Helix geometry model and mechanical property of 3D braided composites

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Abstract

On the basis of available studies, a helix geometry cell model of 3D braided composites is proposed. The yarns in the helix geometry model have been curved to avoid collision at the center of the unit cell and this coincides with the actual configuration of 3D braided composites. Based on the model, the stress field of the unit cell and the stress-strain curve is obtained. The mechanical properties, such as Young's modulus and Poisson's ratio, are calculated by a finite multiphase element method (FMEM). Compared with the experiment results, the study revealed that the helix geometry model prediction is more accurate than the conventional unit cell model.

Keywords: 3D braided composites; Helix geometry model; Mechanical properties

1. Introduction

The utilization of 3D braided composites has developed rapidly in the past years for its excellent mechanical properties. Ma[1] first studied the effective elastic properties of 3D braided composites. Huang and Li [2,3] analyzed the strength of 3D braided composites. Zeng [4-6] predicted the stiffness, strength and nonlinear of 3D braided

composites under the 3D mechanical loading based on the traditional topological model. Surya Kalidindi and Eric [7] developed a helix fiber cell to conduct the numerical evaluation of the 3D braided composite using commercial FE package I-DEAS. However, the yarn and matrix components of the RVE were modeled discretely in meshing and this is quite time-consuming. The main purpose of the present work is to predict elastic properties of 3D braided composites based on the helix geometry model.

2. Unit-cell geometry

A schema for the helix geometry model of 3D braided composites is shown in Fig.1. The yarn center line of the unit-cell is established by a parabola defined by the two yarn end points (located on the top and bottom surface of the cell) and the midpoint of the yarn (located on a plane parallel to and midway between the top and bottom surfaces) and the cross-section of each yarn in XY plane is an ellipse. On the basis of the cell-composition structure of 3D braided composites, a finite multiphase element method (FMEM) [5] has been proposed to predict the mechanical properties of 3D braided composites.

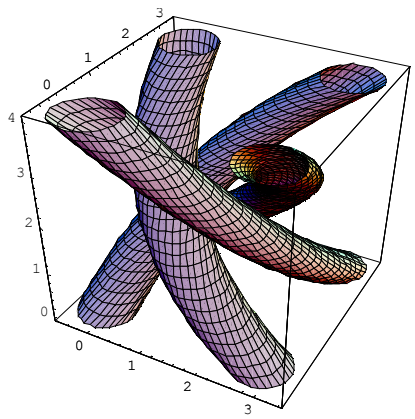


Fig.1. A representative cell of 3D braided composites for helix geometry model

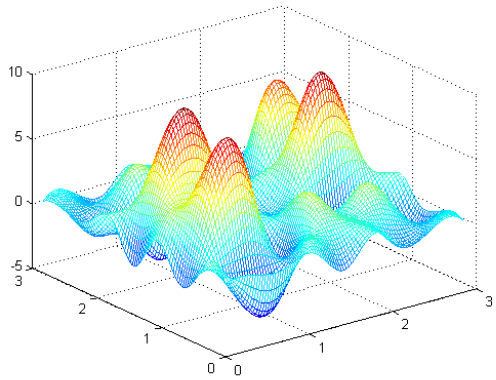


Fig.2. Prediction of σ_z on the plane z=3W/5 of a unit cell

3. Numerical calculation and discussions

3.1 Stress field

The stress distribution of the unit cell is very important because it is used to analyze the failure of 3D braided composites. Fig. 2 depicts the variation of the stress σ_z on the plane z = 3w/5 of a unit cell in the z-direction. It is seen that the stress σ_z in the yarn regions is much higher than that in the matrix region. This indicates that the yarns in 3D braided composites share most of the tensile load.

3.2 Mechanical properties

In this section, the stiffness properties and longitudinal tensile stress-strain relationships of 3D braided composites under the tension loading have been predicted through FMEM based on the helix geometry model. Fig.3 presents the measured and predicted tensile stress-strain curve of 3D braided composites under tension loading. There is a good agreement between the measured and predicted tensile stress-strain in the initial elastic region. During the latter stage, the displacement measured experimentally is higher than the theoretical prediction. Fig.4 shows that the variation of the predicted elastic constants with increasing braiding angle. With increasing braid angle, E_z decreases sharply; γ_{zx} and γ_{zy} firstly increase and then decrease.

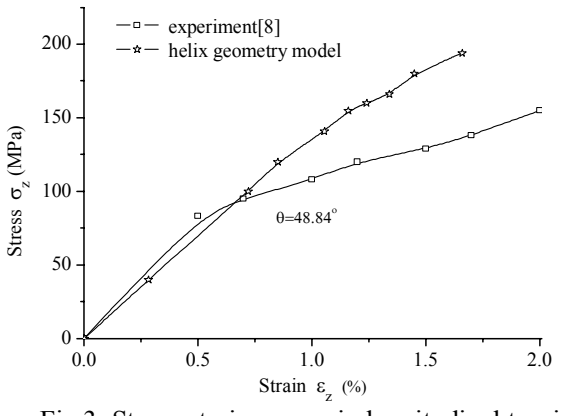
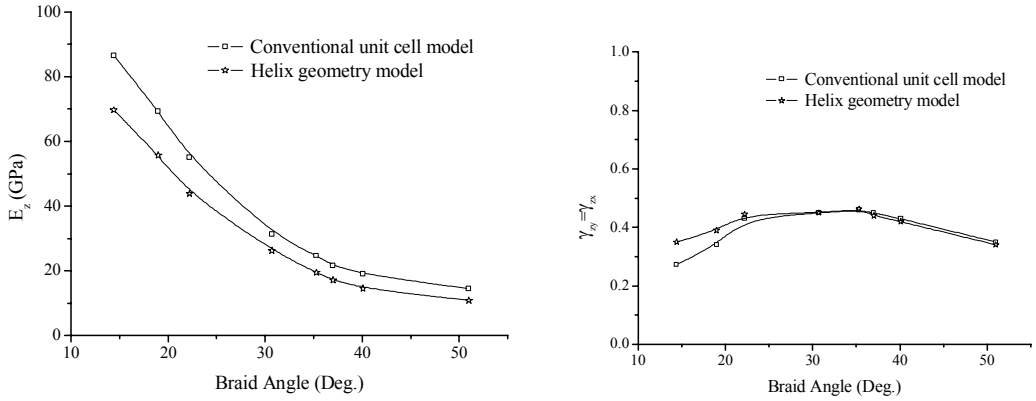


Fig.3. Stress-strain curves in longitudinal tension



(a) (b)

Fig.4. Predicted effective elastic constants against the braid angle

4. Conclusion

This paper presents a helix geometry model, through which the stress field, the longitudinal tensile stress-strain relationships and the elastic constants of 3D braided composites under the tension loading have been predicted. The helix geometry model findings are compared to reported experimental findings in the literature and excellent results are obtained.

5. Reference

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